(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number : 0 670 576 A1

(12) EUROPEAN PATENT APPLICATION

(21) Application number : 95102841.4

(51) Int. Cl.^{6} : G21K 1/06

(22) Date of filing : 28.02.95

(30) Priority : 04.03.94 IT MI940403

(43) Date of publication of application :
06.09.95 Bulletin 95/36

(84) Designated Contracting States :
AT BE CH DE ES FR GB LI

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(54) Grazing incidence co-axial and confocal mirrors.

(57) Grazing incidence co-axial and confocal mirrors, utilizable in particular for X-ray telescopes for astronomic observations, having a parabola/hyperbola double-cone truncated-cone structure, with polynomial sections or other geometric configurations, and comprising an internal reflecting surface (15), constituted by a gold layer, an epoxy resin layer (14) and a supporting mechanical structural element (carrier) (11), constituted by ceramic material having physical-chemical properties improved compared to nickel and obtained according to the process of chemical vapour deposition (CVD) or other fabrication processes.

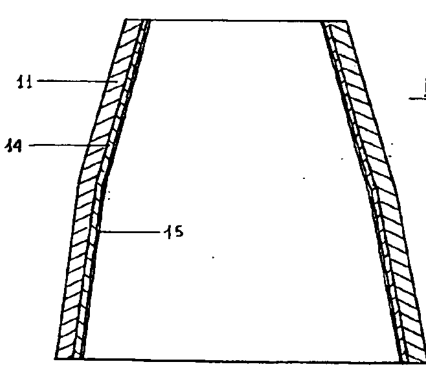

FIG. 2

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This invention relates to grazing incidence co-axial and confocal mirrors. More particularly, this invention relates to grazing incidence co-axial and confocal mirrors particularly suitable to be utilizable in X-ray telescopes for astronomic observations.

The optics of such telescopes is composed by a plurality of coaxial and confocal mirrors, having a parabola/hyperbola double cone truncated cone structure, with polynomial sections or other geometric configurations. Such mirrors are inserted into one another, so as to form a very compact group, are provided with an internal reflecting surface constituted by a very thin gold layer, require extremely accurate preparation technologies and must have special physical characteristics.

In particular, they must have reflective surfaces whose geometry and roughness are provided for in the optical design and extremely thin walls, in order to minimize the loss of collection surface.

The material utilized for their realization must also have the following properties:

- a high modulus of elasticity, in order to have sufficient stiffness with thin thicknesses of the mirrors;
- a very low density to reduce weight as much as possible, as X-ray telescopes have to operate in the space;
- a very low thermal expansion coefficient and a very high thermal conductivity coefficient, in order to minimize optical distorsions due to temperature;
- possibility of being utilized in a replica grating process, being this the only process allowing, thanks to the thin walls, to realize mirrors having high optical qualities, starting from spindles which present the negative of the section required for X-ray optics.

As is known, optical systems for X-ray telescopes are realized utilizing nickel as mechanical structural element for the reflecting material, in a replica grading process through electromolding.

In this process, one utilizes spindles covered by a thin layer (typically 150 μm) of electrochemical nickel (Kanigen). The so covered spindles are optically worked until the geometric sections and the roughness degree (less than lnm RMS) provided for by the optical design are reached.

On the worked spindle, a layer of nickel having a thickness of 0.5-1.5 mm is then deposited by electromolding.

The mirror so obtained, constituted by nickel deposited on gold is then separated from the spindle by cooling the latter.

Separation is facilitated by the fact that the thermal expansion coefficient of aluminium is greater than that of nickel and by the fact that adhesion of gold on electrolitic nickel is much greater than adhesion of gold deposited on the aluminium spindle.

However, this replica grating technology through electromolding has different drawbacks which limit its utilization in designs requiring very high performances as concerns the quality of optical image. These drawbacks include, among others:

- very heavy optical systems, due to the utilization, as mechanical structural element, of nickel, which is a metal having a rather high specific weight (8,8 g/cm^3);
- limited optical quality of reflecting surfaces, because of the deformations due to internal tensions produced during the electromolding process and the distorsions due to the thermal gradients which form because of the high thermal expansion coefficient and the low thermal conductivity of nickel.

Object of this invention is to overcome the aforementioned drawbacks.

More particularly, object of this invention is to overcome the drawbacks characteristics of the mirrors realized from nickel according to the electromolting replica grating process.

More generally, this invention allows to achieve the aforementioned objects by utilizing supporting mechanical structural elements (carriers) realized according to the chemical vapour deposition process or other fabrication processes, from ceramic material having improved physical-chemical properties compared to nickel. In particular, according to this invention, the supporting mechanical structural elements are realized from ceramic material having a specific weight lower than 8.8 kg $m^{-3}10^{3}$, preferably comprised between 2 and 4; a thermal expansion coeffient lower than 14 $H^{-1}10^{-6}$, preferably comprised between 2 and 5; a thermal conductivity greater than 90 W $m^{-1}K^{-1}$, preferably comprised between 150 and 1300, a modulus of elasticity greater than 150 G Pa, preferably comprised between 300 and 700; a thermal distorsion parameter greater than 0.60 W $m^{-1}10^{7}$, a specific rigidity greater than 17 MN $kg^{-1}10^{6}$, preferably comprised between 100 and 350.

Said carriers are suitable to be utilized in a replica grating process with epoxy resin on a spindle from aluminium or other equivalent material. Such replica grating process is well known and has already been experimented on berillium carriers and carriers from plastic material reinforced with carbon fibres.

This invention shall be better understood through the following description wherein reference is made to the attached drawings which represent an embodiment given by way of non limitative example of this invention, and wherein:

Fig. 1 shows the longitudinal section of a truncated cone double cone structure carrier fitted on the spindle; and

Fig. 2 is the view of the longitudinal section of a mirror.

The table lists the physical-chemical properties

of some ceramic materials utilized for the fabrication of said carriers compared to those of nickel.

With reference to the above Figs. 1 and 2, carrier 11 from ceramic material, prepared with the CVD process or another fabrication process, is fitted on spindle 16 from aluminium or other equivalent material, pre-covered with a layer 15 of gold having a typical thickness of about 100 nm. The dimensions of carrier 11 are such as to leave a gap 13, which may be of about 0.1 mm, between said carrier 11 and spindle 16. Such gap 13 is then filled with a fluid epoxy resing 14, which polymerizes and hardens, forming a layer which covers exactly the section of spindle 16. Spindle 16 is then separated by cooling, and in so doing one obtains the detachment of the mirror comprising the gold layer 15, which remains supported by the resin layer 15, anchored, in its turn, to carrier 11 of spindle 16.

Carriers are obtained by means of a CVD process and are constituted by silicon carbide (SiC) and boron azide (BN).

According to a variant of this embodiment, carriers may also be prepared by means of a reaction syntherization process and are constituted by silicized silicon carbide and silicon. Such material is available on the market under the trade name CERAFORM, produced and sold by United Technology Optical System, West Palm Beach, FL (USA).

The utilization of carriers fabricated according to this invention allows to obtain mirrors having a very wide range of thicknesses, comprised generally between 0.3 and 10 mm. However, such carriers prove to be particularly suitable to prepare mirrors having very reduced thicknesses and typically comprised between 0.4 and 1 mm.

The aforementioned materials and in particular silicon carbide and boron azide, besides eliminating the above mentioned drawbacks arising from the utilization of nickel as mechanical structural element, allow also to achieve further advantages due to their physical-chemical characteristics specified in the table, and in particular:

- they provide the opportunity of obtaining mirrors having a better mechanical stiffness with smaller thicknesses, as they have a modulus of elasticity and a specific stiffness much greater than nickel; and
- they can undergo more easility the replica grating operation, as they have, as has been already mentioned, a thermal expansion coefficient much smaller than nickel.

The mirrors according to this invention are applied, not only in the field of X-ray telescopes, but also in other fields, such as, for instance, optics for X-ray microscopes and optics for lithographic utilizations.

Although the invention has been described with reference to specific and particular realization conditions, it is obvious that those expert in the art can introduce alternatives and changes, in the light of the above description.

Hence the invention covers any alternative and modification which fall within the concept and the protection scope of the following claims.

Claims

1. Grazing incidence co-axial and confocal mirror, having a parabola/hyperbola double cone truncated cone structure, with polynomial sections or other geometric configurations, said mirror comprising an internal reflecting surface (15), constituted by a gold layer, an epoxy resin layer (14) on which said gold layer is supported, and a mechanical structural supporting element or carrier (11), to which the resin layer (14) is anchored, characterized in that said carrier (11) is from ceramic material having a specific weight smaller than 8.8 kg $m^{-3}10^3$, a thermal expansion coeffieicnt smaller than 14 $K^{-1}10^{-6}$; a thermal conductivity greater than 90 W $m^{-1}K^{-1}$, a modulus of elasticity greater than 150 G Pa, a thermal distorsion parameter greater than 0.6 W m^{-1} and a specific stiffness greater than 17 MN $kg^{-1}10$.

2. Mirror according to claim 1, characterized in that the ceramic material has a specific weight comprised between 2 and 4 kg m^{-3} 10^3, a thermal expansion coefficient comprised between 2 and 5 $K^{-1}10^{-6}$, a thermal conductivity comprised between 150 and 1300 W $m^{-1}K^{-1}$, a modulus of elasticity comprised between 300 r 700 Pa, a thermal distorsion parameter comprised between 5 and 28 W m^{-1} 10^7 and a specific stiffness comprised between 100 and 350 MN $kg^{-1}10^6$.

3. Mirror according to claim 1 or 2, characterized in that carrier (11) is prepared by means of a chemical vapour deposition process (CVD).

4. Mirror according to any of the preceding claims, characterized in that the ceramic material is constituted by silicon carbide.

5. Mirror according to any of the preceding claims 1 through 3, characterized in that the ceramic material is constituted by boron azide.

6. Mirror according to any of the preceding claims 1 or 2, characterized in that said carrier (11) is made from silicized silicon carbide and is prepared by means of the reaction syntherization process.

7. Mirror according to any of the preceding claims, characterized in that said mirror has a thickness

comprised between 0.3 and 10 mm.

8. Mirror according to any of the preceding claims, characterized in that said mirror has a thickness comprised between 0.4 and 1 mm.

9. Utilization of the mirror according to any of the preceding claims in the optics for X-ray telescopes utilized for astronomic observations.

10. Utilization of the mirror according to any of the preceding claims 1 through 9 in the optics for X-ray microscopes and for lythographic utilizations.

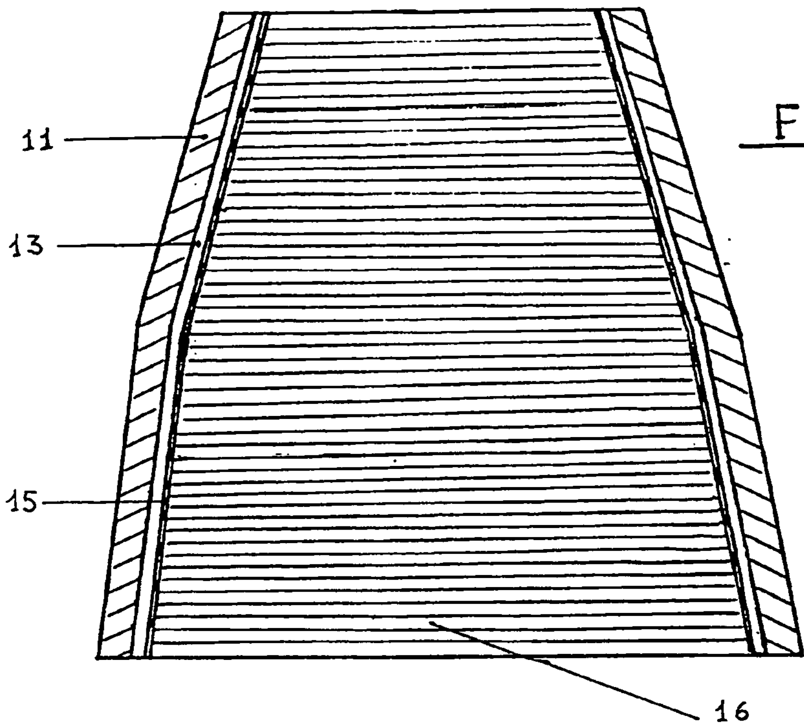

FIG. 1

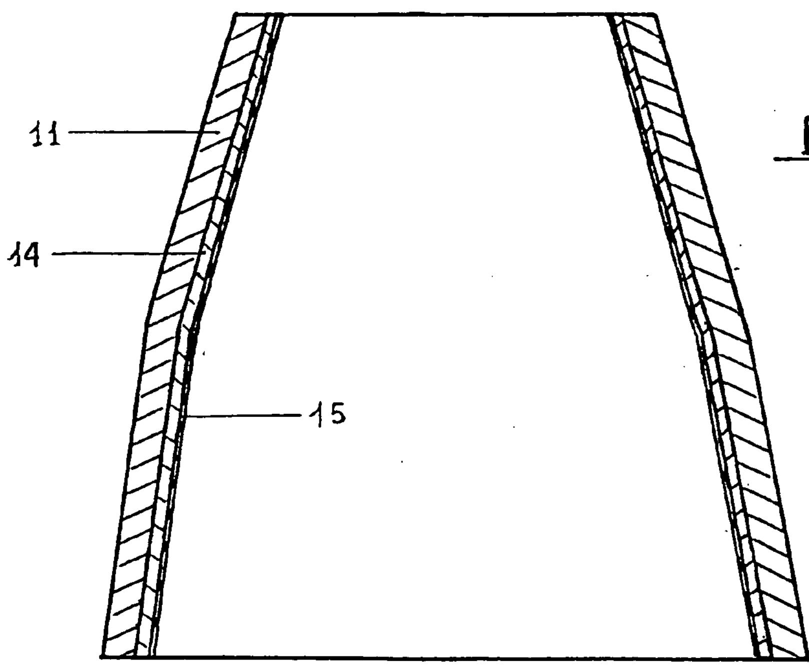

FIG. 2

MATERIAL	SPECIFIC WEIGHT ρ (kg $m^{-3} 10^3$)	THERMAL EXPANSION COEFFICIENT (TEC) α ($K^{-1} 10^{-6}$)	SPECIFIC HEAT c ($Jkg^{-1}K^{-1}$)	THERMAL CONDUCTIV. k ($Wm^{-1}K^{-1}$)	MODULUS OF ELASTICITY E (G Pa)	THERMAL DISTORSION PARAMETER $k \alpha^{-1}$ ($W^{-1} 10^7$)	SPECIFIC STIFFNESS $E.\rho^{-1}$ (M N $kg^{-1} 10^6$)
Nickel	8,8	14	--	90	150	0,6	17
SiC (CVD	3,21	2,4	700	250	466	10,4	145
BN (CVD)	2,0	4,7	--	1,300	646	28	323
SiC + Si (CERAFORM)	2,92	2,6	--	156	310	6,0	106

FIG.3

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EUROPEAN SEARCH REPORT

Application Number
EP 95 10 2841

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	GB-A-1 045 016 (A. ELLIOT) 5 October 1966 * page 1, line 35 - line 83 * * page 2, line 13 - line 15 * * page 2, line 89 - page 3, line 8 * * page 4, line 29 - line 39 *	1,10	G21K1/06
A	EP-A-0 343 861 (TOKYO SHIBAURA ELECTRIC CO) 29 November 1989 * column 1, line 1 - line 4 * * column 3, line 31 - line 43 * * figures 1,2 *	1,10	
A	US-A-4 370 750 (HOOVER RICHARD B) 25 January 1983 * column 3, line 38 - line 49 *	1,9	
A	DATABASE WPI Week 8426 Derwent Publications Ltd., London, GB; AN 84-162145 & JP-A-59 087 404 (HITACHI) , 21 May 1984 * abstract *	1,2,4	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	PATENT ABSTRACTS OF JAPAN vol. 14 no. 463 (E-988) ,8 October 1990 & JP-A-02 188908 (FUJITSU) 25 July 1990, * abstract *	3,4	G21K G02B
A	DATABASE WPI Week 8822 Derwent Publications Ltd., London, GB; AN 88-151682 & JP-A-63 092 915 (IBIDEN) , 23 April 1988 * abstract *	4-6	
A	US-A-4 554 197 (CHYUNG KENNETH ET AL) 19 November 1985 * column 2, line 53 - column 4, line 11 *	1,2,4,6	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29 May 1995	Capostagno, E

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
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